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**14. ABSTRACT**

Initial research was performed on the Brute synthetic task for unmanned flight (based on the Predator system). This research indicated that spatial orientation was a major difficulty that people had in performing this task. Many participants made many errors in their directional judgments. A series of experiments were performed systematically investigating the difficulties people had in integrating a map view of a terrain with a camera view available from a plane. Two strategies were identified for bringing the map view and the camera view into alignment. One strategy involved mentally rotating the camera view until it was in alignment with the map view. The second strategy involved calculating the offset of various targets in the camera view and adding that offset to the direction of orientation in the map. Cognitive models in ACT-R were developed that implemented both of these strategies and fit to eye movements of participants. Part of this effort involved developing an imagery module for ACT-R that can be used more generally to model navigation. The final report describes in more detail the nature of the experimentation, the results, and the ACT-R model.

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## Final Performance Report
## AFOSR F49620-99-1-0086

## Objectives

The general goal of our project has been to use cognitive modeling to improve training in synthetic tasks of interest to the Air Force. For this particular project we initially chose to focus on the Brute simulation of unmanned flight that was developed at Brooks Air Force Base. We had hoped to work closely with the people at Brooks Air Force Base on this task but that has proven not possible with the reduction of the laboratory there. Therefore, we were left on our own and chose to identify what was conceptually difficult about the task. We identified three features: processing of instruction, categorizing perceptual information, and making spatial judgments. While we did work on all three we focused most on the third since Gugerty, deBoom, Jenkins, and Morley have shown that it poses significant difficulties to Air Force recruits. Our goal has been to develop ACT-R cognitive models of these aspects of the task that could serve as a basis of instructional intervention.

## Status of Effort

We completed an initial study of skill acquisition in the full Brute simulation. Subsequent to this, we have completed empirical studies of all three components chosen for study – processing of instruction, categorizing perceptual information, making spatial judgments. ACT-R models were developed for aspects of each of these three components.

## Accomplishments/ New Findings

The initial study of skill acquisition revealed that, while participants improved systematically with practice, they continued to have residual difficulties with processing of messages, judgments of perceptual information, and spatial judgments. Work was done on modeling real-time instruction processing both in terms of the syntactic and semantic processing involved and in terms of the conversion of this information into effective procedures. This contributed to the ongoing development of a general instruction module for ACT-R. A series of experiments were performed documenting the effects of past experience on categorization of perceptual information. An ACT-R model called Anchor was developed that modeled these data and a good bit more from the psychophysics literature.

The basic spatial task involved in Brute involves relating information displayed on a plane-mounted camera and the information displayed on a map of the region. This map is typically displayed in the canonical north-up orientation with representation of the location of the plane and camera angle and target. Integrating the camera view and the map information involves relating two frames of reference – the camera view provides what is called an egocentric frame of reference and the map view provides what is called an allocentric frame of reference.

Our initial study looked at whether participants would improve at a spatial task with extensive practice and how they would improve. There are two related tasks typically found in the Brute

simulation. One involves judging the cardinal direction of an object in the camera view and the other involves identify the object that is in a specified cardinal direction. We have looked at both tasks in the laboratory but have focused mainly on the first. In this task participants are asked what direction a particular point is in the camera view and given a map view with an indication of the direction of the camera. Most participants initially report rotating themselves mentally in space to adopt the position of the camera view in the map, determining the angle of the point in the camera view, and then "pointing" to that position in the map view. This reflects their effort to bring the egocentric and allocentric points of view into alignment. However, such judgments can be made more simply and accurately by simpler rotational or clock-counting strategies. In both strategies the camera view is no longer treated as an egocentric point of view. In the rotational strategy they rotate the camera view until its position of the object is aligned with the position in the map view. In the counting strategy they count the number of clock ticks the target is from 6 o'clock in the camera view and apply that same count to the map from the plane position. With extensive practice participants come to adopt some mixture of these strategies. Over the course of an hour experiment participants improved their speed in making these judgments by a factor of 2.

We then developed a simulation of this task in the ACT-R/PM architecture. The ACT-R/PM architecture integrates a sophisticated theory of cognition, ACT-R, with a theory of perceptual and motor processing. The cognitive system gives us the ability to accurately model the cognitive demands of the task and the perceptual and motor modules allow us to model integration of cognition with perception and cognition. Each of these modules can process information in parallel with the other modules but within each module information processing is serial. This serial-parallel combination allows us to model both the information-processing demands and opportunities created in a multi-tasking environment.

We actually developed two models in ACT-R/PM that reflected the two strategies that participants evolved towards – the strategy where they rotated the camera view and the strategy where they counted clock ticks. The two models made somewhat distinct predictions but neither really corresponded to the data which we felt resulted from a mixture of the two strategies. Therefore, in a follow-up study we trained different participants on these two strategies and found that the models did fit the data of the participants trained with the appropriate strategy. Moreover, the trained participants more quickly achieved high level of performance than the untrained participants. These two strategies make two distinct predictions about eye movements and we completed an eye movement study that confirmed these predictions.

## Personnel Supported:

| | |
|---|---|
| Faculty: | John R. Anderson |
| Post Docs: | Myeong-Ho Sohn, Alex Petrov |
| Graduate Students: | Raluca Budiu, Glenn Gunzelmann, Jan Misker, Philip Pavlik |
| Programmer: | Mary Hart |

## Publications:

Budiu, R. & Anderson, J. R. (2000). Integration of background knowledge in sentence processing In *Proceedings of the Third International Conference on Cognitive Modeling*, pp. 50-57, University of Groningen, Netherlands.

Petrov, A. & Anderson, J. R. (2000). ANCHOR: A memory-based model of category rating. In *Proceedings of the Twenty-Second Annual Conference of the Cognitive Science Society* (pp. 369-374)..

Budiu, R. (2001) The role of background knowledge in sentence processing, Doctoral Dissertation, Department of Computer Science, Carnegie Mellon University, Pittsburgh, PA.

Petrov, A. (2001). Fitting the ANCHOR model to individual data: A case study in Bayesian methodology. In *Proceedings of the 2001 International Conference on Cognitive Modeling*, pp. 174-180. Mahwah, NJ: Lawrence Erlbaum Associates.

Pavlik Jr., P. I., & Anderson, J. R. (2002). Mental rotation transfer. Poster presented *the 24th Annual Meeting of the Cognitive Science Society*, Fairfax, VA August 2002.

Gunzelmann, G., & Anderson, J. R. (in press). Strategic differences in the coordination of different views of space. *In Proceedings of the 24th Annual Meeting of the Cognitive Science Society* (pp. 387-392). Fairfax, VA: August, 2002.

## Interactions/Transitions:

We visited Brooks Air Force Base in 1999 where we discussed common research interests.

## New Discoveries, Inventions, or Patent Disclosures:

None

## Honors/Awards:

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|---|---|
| 1999 | National Academy of Sciences |
| 1999 | Fellow, American Academy of Arts and Sciences |
| 2000 | University Professor, Carnegie Mellon University |
| 2001 | National Academy of Sciences, Psychology Section Chair |
| 2002 | Richard King Mellon Professor of Psychology and Computer Science |